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Preoperative fasting guidelines in pediatric anesthesia: are we ready for a change?

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Study after study shows that prolonged fasting before anesthesia is common in children. Pediatric anesthesiologists around the world are concerned that the current guidelines may be part of the problem. This review focuses on what can be done about it.

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Video abstract
http://links.lww.com/COAN/A50

Keywords
aspiration pneumonia, children, fasting hypoglycemia, gastric emptying, perioperative period

INTRODUCTION

The general purpose of preoperative fasting is to allow enough time for the stomach to empty, and hence reduce the incidence of regurgitation of gastric contents into the trachea. Most modern fasting guidelines take into account the balance between the risk of pulmonary aspiration and the harmful effects of prolonged preoperative fasting. In this review, we describe the background to the current guidelines and discuss the issue of prolonged fasting commonly occurring in children. We examine the physiologic basis for fasting and the negative effects of prolonged fasting. We will also critically appraise the concept of a strict association between fasting time and the risk of aspiration and look into the most recent research in the field that have made us suggest that the time may be right for an update of the current recommendations.

FASTING GUIDELINES: PAST AND PRESENT

Preoperative fasting was recommended as early as the 19th century. In those days, it was primarily to protect the staff from the inconvenient event of patients vomiting. The best time for an operation under chloroform was recommended to be before breakfast or just before lunch [1]. In 1883, Lister published practical fasting guidelines suggesting that there should be no solid matter in the ventricle. However, he also suggested that tea or beef-tea 2 h before anesthesia was beneficial for the patient. This distinction between solids and fluids was blurred in the 1960s when most institutions adopted the 'nil by mouth from midnight' (NBM) fasting regimen for elective healthy patients. The NBM regimen was straightforward to follow, easy for patients to understand and, if cancellation occurred, there was no problem with operating on another patient earlier than scheduled [1].

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KEY POINTS

- Prolonged preoperative fasting is still common in children.
- Gastric emptying of a drink of milk or milk-based product, or even a light breakfast including solids may be complete within 4 h.
- Even large amounts of clear fluids pass through the stomach well within an hour.
- Several pediatric centers report benefits of allowing children clear fluids up to 1 h or less before surgery.

Subsequently, several studies showed that more liberal fasting regimens with 2-h fasting for clear fluids do not increase gastric content volume in adults or children, eventually leading to the publication of several new guidelines for preoperative fasting [2▪,3,4].

The American Society of Anesthesiology (ASA) recommends children to be fasted 6 h for solids, 4 h for breast milk and 2 h for clear fluids [2▪]. The European Society of Anaesthesiology (ESA) and the Scandinavian guidelines follow the ASA recommendations but differ regarding infant formula where they recommend fasting for 4–6 h prior to surgery [3,4]. Both ESA and the Scandinavian guidelines recommend that children and adults should be encouraged to drink clear fluids up until 2 h prior to surgery, with the purpose of attenuating potential unwanted effects of prolonged fasting [3,4].

COMPLIANCE TO FASTING REGIMENS

The current guidelines thus represent a significant step forward from the NBM from midnight regimen, and many patients have benefited from the more liberal 2-h limit for clear fluids. In spite of this, several reports of prolonged fasting intervals have been published (Table 1). It has proved difficult to take full advantage of the 2-h fasting rule. In pediatric studies of actual preoperative fasting times, the 2-h regimen for clear fluids led to as much as 21 h of fluid-fasting [5–8,9▪,10▪▪].

It seems to be exceedingly difficult to keep a large proportion of children from fasting less than 6 h, as long as the 2-h limit is strictly implemented. The main reason is that a 2-h limit for clear fluids demands a reliable assumption of when each procedure will start. Acute cases, rearrangements of the surgical lists and cancellations occur daily in busy surgical units. This often leads to prolonged fasting both for children who are rescheduled and for those who are kept fasted 'just in case'. Furthermore, many young children are scheduled as first case in the morning and will thus, if they sleep all night, be fasted since having their evening meal. Other reasons for children being fasted longer than recommended are incorrect instructions from healthcare personnel and parents not understanding or not following instructions [7].

THE PHYSIOLOGY OF GASTRIC EMPTYING

The purpose of preoperative fasting is to achieve an empty stomach. So, when can the stomach be considered to be empty? We can never be sure, as we shall see. An observational study using MRI in children demonstrated that the stomach is not empty even after a prolonged fasting time [6]. This was corroborated by a recent ultrasound study in which 5% of elective adult patients were found to have a gastric residual volume larger than expected [11▪]. Thus, the anesthesiologist must be aware of this variability and be prepared for the child that vomits at induction, regardless of fasting time. However, the majority of patients behave according to the physiology of gastric emptying, of which we must have a thorough understanding.

Gastric content: more than food and drink

The volume of gastric contents is the sum of food and fluid intake, swallowed salivary and gastric

Table 1. Reported fasting times in children when applying the 6–4–2 regimen

Reference	Fasting time clear fluids mean/median ± SD (range)	Fasting time breast milk	Fasting time solids mean/median (range)
Engelhardt *et al.* [5]	8 (0–21)		12 (1–22)
Schmitz *et al.* [6]	5.5 (1.1–15.5)		6.7 (4–20.2)
Cantellow *et al.* [7]	5 (0.5–24)		9.5 (3–40)
Arun *et al.* [8]	4 (2–8.3)		9 (4.8–13.5)
Dolgun *et al.* [9▪]	10.5	6.27	
Newton *et al.* [10▪▪]	6.3 ± 4.5		

secretions minus the gastric juice emptied through the pylorus. As part of the digestive process, the stomach accommodates ingested food functioning as a flexible reservoir, breaks it down mechanically as well as chemically and delivers the fluid chyme that is produced into the intestine at a controlled rate. Gastric secretions consist of hydrochloric acid, mucus and other secretions. Gastric acid is secreted by the proton pump of the parietal cells in a dynamic, variable and highly regulated process involving neural, hormonal and paracrine pathways as well as mechanical or chemical stimulation, for example wall distention and nutrient constituents [12]. The amount of gastric secretion is extremely variable and can even exceed the volume of ingested food. Also salivary production, which contributes to gastric volume via swallowing, is quite variable with basal and stimulated rates of about 0.5 and 1.2 ml/min, respectively, in adults [13]. The short-term maximum rate may be greater than 10 times the unstimulated rate.

Gastric emptying of solids and liquids

Gastric emptying relies on a feedback mechanism from nutrient composition and volume detected in the stomach and small bowel and conveyed via local sensory nerves, vagal afferent nerves and several stimulatory or inhibitory hormones. Furthermore, metabolic needs and control mechanisms such as blood sugar play a role in neurohormonal regulation of gastric emptying [14].

Liquids and solids have different emptying kinetics, with elimination of liquids following first order kinetics. However, an initial rise of gastric volume due to gastric secretion may occur, so that the emptying of liquid nutrients may more precisely be described by more complex models [15]. Gastric emptying of solids is divided into two phases: first, a lag phase which lasts up to 60 min depending on the ingested volume, and during which nutrients are mixed and redistributed within the stomach and broken down to particles not larger than 1–2 mm. The lag phase is followed by a linear emptying phase (Fig. 1) [14].

Cow's milk is separated into clear fluid and a semisolid curd, which is eliminated at a slower rate than human milk. The emptying pattern shows an initial fast emptying, followed by a slower linear emptying phase. A recent radionuclide study reported a half-life value of 81 min for gastric emptying of 200-ml cow's milk in healthy children [16], whereas an ultrasound-based study reported a probability of 95% that almost 300 ml of 2% cow's milk was eliminated within 202 min [17▪].

As gastric emptying is a complex and highly regulated process, it may be influenced by various stimuli and conditions, such as composition of nutrients, that is fat, carbohydrates or proteins,

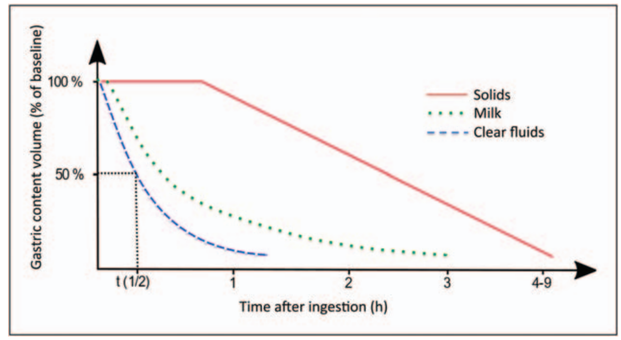

FIGURE 1. Gastric emptying pattern of solids (red colored line), cow's milk (green dashed line) and clear fluids (dotted blue line). Solids are cleared in a linear manner following a lag phase. Total emptying time depends on the caloric density of the meal. Cow's milk displays an initial fast phase followed by more or less linear emptying. Liquids follow first-order kinetics with a half-life of 10–26 min.

caloric content, tonicity and temperature of gastric contents. Several studies on liquid emptying using MRI have shown that the half-life depends on the composition of nutrients [18], caloric load, carbohydrate content and the degree of carbonation [19].

Furthermore, anxiety or fear, position and exercise may have an impact on emptying rate, and particularly diverse substances and medications, for example alcohol, antacids, ondansetron or opoid analgesics, to mention just a few. A number of disorders and diseases, for example chronic renal failure, several central or peripheral nervous system disorders, myotonic dystrophies, psychiatric disorders autoimmune or infectious diseases, abdominal diseases or surgical states, may cause delayed emptying [20]. Critically ill patients with parenteral nutrition or sedation, while exposed to several drugs and often suffering from several disorders, may thus be expected to have a slower gastric emptying.

Gastric emptying in different age groups

Gastric function, and consequently gastric emptying, changes during childhood development. Far less is known compared with gastric function in adulthood for ethical and practical reasons [21]. Intrauterine gastric motility and secretion commence at approximately 20 weeks of gestational age, followed by the swallowing of amniotic fluid around 26 weeks, further promoting gastric motility and emptying [21]. According to Heyman, gastric receptive relaxation is absent in the newborn, which may explain their higher incidence of reflux compared with older children. There are no antral peristaltic contractions in the first few days of life, accounting for delayed gastric emptying in newborns whether premature or term [22]. Normal neuromuscular innervation and contractile activity are not established until near birth, and altered emptying patterns have been found by gastric ultrasonography in preterm babies [23]. However, in a recently published meta-analysis, there was no link between age and gastric emptying when comparing 1457 patients, from neonates to adults [24].

NEGATIVE EFFECTS OF FASTING

Long fasting intervals can be harmful for pediatric patients. Children are more sensitive to fasting than adults due to smaller stores of glycogen in liver and muscles, and the younger the child, the faster hypoglycemia and ketogenesis will develop [25].

During fasting, insulin levels decrease and high concentrations of free fatty acids increase insulin resistance in muscle tissue, which may be harmful in combination with surgical stress. During surgery, stress hormones like catecholamines, cortisol and glucagon are released and further increase insulin resistance. Postoperative insulin resistance leads to postoperative hyperglycemia and is related to an increased risk of postoperative complications. The degree of postoperative insulin resistance is also associated with postoperative length of hospital stay, indicating that postoperative insulin resistance influences postoperative recovery [26].

Shortened fasting times reduce concentration of ketone bodies, osmolality and anion gap [27▪] and diminish postoperative insulin resistance [28]. Shortened fasting time for clear liquids will preserve intravascular volume and thus improve hemodynamic conditions [27▪]. Children allowed clear liquids before surgery appear less likely to show signs of dehydration such as prolonged capillary refill, absence of tears, dry mucous membranes and unwell appearance [29].

Fasting leads to thirst, hunger and anxiety. Not surprisingly, several studies show that children allowed to drink prior to surgery show less thirst, hunger and discomfort, than children that are kept fasting from midnight [2▪,5,9▪,29]. Although thirst is most disturbing in the subjective perception of adults, hunger seems to be a more prominent problem than thirst in children [30].

PULMONARY ASPIRATION AND PREOPERATIVE FASTING

Pulmonary aspiration of particulate matter, resulting in mechanical obstruction, is an entity different from the classic acid aspiration which causes a chemical injury causing aspiration pneumonitis, although the two may occur simultaneously. In the Fourth National Audit Project, aspiration of gastric contents was the most common cause of death associated with anesthesia in adults [31]. Furthermore, the incidence of perioperative pulmonary aspiration in pediatric patients is higher than in adults, ranging from one to 10 in 10 000 [32,33▪,34]. This is most likely due to a smaller ventricle, increased gastric pressure, extensive diaphragm breathing and swallowing of air during crying. However, in children, the consequences are often mild [33▪,34]. To date, no reports of mortality due to pulmonary aspiration in children have been published.

Several conditions have been associated with an increased risk of pulmonary aspiration, such as a high ASA grade, emergency surgery, gastroesophageal reflux, dysphagia symptoms, gastrointestinal motility disorders, neuromuscular disorders, obesity and diabetes mellitus. These are all conditions that delay gastric emptying, increase regurgitation or impair protective airway reflexes.

Few studies of risk factors for perioperative pulmonary aspiration have been performed in the pediatric population. In the studies that have attempted to investigate the relationship between pulmonary aspiration and fasting status, no correlation has been detected [35]. In addition to the low incidence of pulmonary aspiration, the weak association between fasting interval and gastric residual volume (Table 2) implies a low likelihood of such an association.

Table 2. Randomized clinical trials comparing nil by mouth after midnight versus shorter fasting intervals for clear fluids in children

	GCV after fasting (ml/kg)				
Reference	**Overnight**	**3 h**	**2 h**	**1 h**	**0.5 h**
Sandhar *et al.* [36]	0.25		0.34		
Schreiner *et al.* [37]	0.57		0.44		
Splinter *et al.* [38]	0.39	0.34			
Litman *et al.* [39]			0.3		
Schmitz *et al.* [40]	0.62		0.32	1.27	2.92
Schmitz *et al.* [41]	0.39			0.45	
	0.34			1.33	
Schmidt *et al.* [42]			0.46	0.43	

GCV, gastric content volume.

Furthermore, allowing clear fluids 0–1 h prior to surgery has not been found to increase the incidence of pulmonary aspiration [10▪▪,34]. Fluids and mucus are always present in the trachea and should be. In contrast, aspiration of solid material obstructing the airway is a serious incident that demands immediate action toward clearing the trachea. Fasting times for solids should therefore be set at 6 h, and for large, high-calorie meals even longer fasting intervals would be prudent. In contrast, gastric content of clear fluids does not seem to affect the risk of pulmonary aspiration. Several studies of the incidence of aspiration have instead emphasized that proper airway management and proper pediatric anesthesia training may be the most important factors to minimize the risk of pulmonary aspiration [31,33▪].

PUSHING THE LIMITS: TOWARD A CHANGE IN THE GUIDELINES?

In clinical practice, the 6–4–2 fasting regimen only enables minimization of fasting times for patients scheduled as first case of the morning list, and even then fails in many cases. For the rest of the list, the patients are given approximated times for the start of surgery and are accordingly fasted far longer than 2 h. This issue has been successfully addressed by improving the communication between the surgical theater and ward and multidisciplinary information campaigns [27▪]. However, evidence for the optimal preoperative fasting time for children is still lacking. Let us have a look at the three components.

Solids: the 6-h limit

In contrast to regurgitation with clear fluids, aspiration of solid matter may lead to airway obstruction. The stomach should thus be entirely emptied from solids before induction. High-caloric meals may actually take longer to empty than the currently recommended 6 h. A conservative approach would thus be to advocate going back to 'NBM from midnight' for solids. In a radionuclide study of a moderate calorie vegetarian meal (280 kcal) there was some retention in 21% of children at 4 h [43▪]. In contrast, a light breakfast may be emptied from the stomach well within 4 h in healthy preschool children [44,45]. Thus, the caloric content and the composition and volume of the meal will affect whether a reduction to 4 h fasting for solids could be well tolerated. There is reason to believe that a well defined light meal of for example tea and toast (as in the old days) or a single fruit would be perfectly well tolerated and much appreciated by children not enjoying gruel or formula. Furthermore, the odd child who has had a piece of banana or bread by mistake could no doubt also be safely anesthetized after 4 h instead of being cancelled that day. However, more research is needed to demonstrate that there is no risk of residual solid before this approach could be incorporated into forthcoming guidelines. A key issue is if it is possible to define a meal 'light enough' to be digested within 4 h in almost all children. Furthermore, the challenging problem of informing parents and children of this hypothetical well tolerated meal of solids may in some settings not be worth the effort.

Milk and milk-based semisolids: moving toward a 4-h limit

Even the smallest amount of milk is regarded as a solid in the ASA guidelines. As we have discussed above, the reason is that milk proteins form a curd in the stomach and would accordingly be expected to follow zero-order kinetics. However, this applies to only a small portion of a milk-based product, whereas the rest is clear fluid. Gastric emptying of a reasonable amount of milk-based product will therefore be completed within considerably less time than after the same amount of solids. Indeed, two recent studies confirm that as much as 300 ml of milk takes less than 4 h to pass through the stomach [17▪,46]. In the Scandinavian guidelines, the recommended fasting interval for milk-based formula is 4 h. In Uppsala, Sweden, children are encouraged to eat milk-based products such as yoghurt, soup and formula until 4 h before anesthesia. This practice has been in place since the year 2000 and was audited together with the free clear fluid regimen, showing no signs of increased risk of pulmonary aspiration or other complications [34]. We think there is enough evidence to recommend other pediatric centers to do the same, and recommend the authors of upcoming updated guidelines to consider a 4-h limit for semisolids including milk-based products.

Clear fluids: time to reduce the 2-h limit

The research leading to the recommendation of a minimum of 2-h fasting for clear fluids mainly focused on proving noninferiority of this regimen compared with the traditional 'NBM after midnight'. What we now know about gastric emptying suggests that even shorter fasting intervals may be well tolerated. In accordance with the latter insight, several centers have adopted more liberal fasting regimens for clear liquids and/or a light breakfast of semisolids. In Sweden and Australia, there are hospitals that allow children clear fluids until called to surgery [34,47], and in the United Kingdom, several centers are allowing clear fluids until 1 h prior to anesthesia induction in line with a recent publication [10■■]. In the latter study, the switch to a 1-h fasting limit for clear fluids was associated with a reduction in mean fasting time to 3 h, and the authors stressed the benefit of being able to offer ambulatory children a drink on arrival at the day-care unit as well as empowering ward nurses to call to theater when they anticipated prolonged fasting intervals in some children. Similarly, introduction of the 6–4–0 fasting regimen resulted in reduced mean fasting time from four to 1 h. More importantly, the incidence of fasting more than 6 h was significantly reduced [48■]. We would therefore recommend more leading pediatric anesthesia departments to reduce the fasting limit for clear fluids to 1 h or lower, ideally while auditing the transition in a multicenter collaboration. Although the recent publications clearly show the benefits of such a regimen and do not report increased incidences of aspiration, they were not powered to establish non-inferiority. However, the discussion on physiology above clearly shows that a 1 h limit for clear fluids is very likely to be as safe as the current 2-h limit, and should therefore be considered in any new guidelines on pediatric preoperative fasting.

CONCLUSION

Shorter fasting intervals may be well tolerated for clear fluids, milk-based products and even a light meal consisting of a limited amount of solid food. The benefits of allowing clear fluids up to 1 h or less before surgery have been shown in several studies. Our view is that pediatric hospitals could consider changing their fasting recommendations regarding clear fluids, but should do so while auditing safety, ideally as a multicenter effort. It may be too early to recommend more liberal limits for solids and milk-based semisolids for all children, but with further studies, this could be possible in the near future.

Finally, regardless of fasting regimen, we can never be sure that the child coming to the operating room has an empty stomach. Properly trained pediatric anesthesiologists with adequate skills and updated equipment, as well as a safe plan for induction, remains the mainstay of preventing complications in pediatric anesthesia.

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Conflicts of interest

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